

Claims

1. A method of manufacturing metal nanostructures comprising:
  - identifying a desired shape for the metal nanostructures,
  - forming the metal nanostructures under reaction conditions optimized to yield the desired shape at a higher percentage than any other nanostructure shape,
  - separating the nanostructures having the desired shape from nanostructures of other shapes.
2. The method of claim 1, wherein the separating comprises filtering nanostructures having the described shape from nanostructures of other shapes.
3. The method of claim 1, wherein the separating is achieved by gravity.

4. A method of manufacturing silver nanostructures having a desired shape such as nanospheres, nanocubes, nanowires, nanoparamids and multiply twinned nanoparticles, the method comprising:

obtaining a solution of silver nitrate in ethylene glycol,

obtaining a solution of poly (vinyl pyrrolidone) in ethylene glycol,

selecting reaction conditions to yield a silver nanostructure having a desired shape, wherein the reaction conditions comprise silver nitrate concentration, poly (vinyl pyrrolidone) concentration, reaction temperature and reaction time, and

combining the solution of silver nitrate in ethylene glycol and the solution of poly (vinyl pyrrolidone) in ethylene glycol together and allowing a reaction to occur at the reaction temperature over the growth time.

5. The method of claim 4, wherein the reaction conditions are selected to yield a desired shape at a percentage higher than any other nanostructure shape.

6. The method of claim 5, wherein the method further comprises separating nanostructures having the desired shape from nanostructures of other shapes.

7. The method of claim 4, wherein the solution of silver nitrate in ethylene glycol and the solution of poly(vinyl pyrrolidone) in ethylene glycol are combined simultaneously to a volume of ethylene glycol.

8. The method of claim 4, wherein the nanostructures are nanocubes.
9. The method of claim 4, wherein the nanostructures are nanowires.
10. The method of claim 4, wherein the nanostructures are nanopyramids.
11. The method of claim 4, wherein the nanostructures are multiply twinned particles.

12. A method of manufacturing silver nanocubes comprising:
  - preparing a solution of silver nitrate in ethylene glycol, wherein the concentration of silver nitrate ranges from about 0.1 mol/dm<sup>3</sup> to about 0.3 mol/dm<sup>3</sup>,
  - preparing a solution of poly(vinyl pyrrolidone) in ethylene glycol, wherein the concentration and amount of poly(vinyl pyrrolidone) solution is sufficient to provide a ratio of poly(vinyl pyrrolidone) to silver nitrate ranging from about 1.5 to about 3, and
  - combining the silver nitrate solution and poly(vinyl pyrrolidone) solution and allowing the mixture to react at a temperature ranging from about 155° C to about 175° C for a time ranging from about 10 minutes to about 60 minutes.

13. The method of claim 12 wherein the poly(vinyl pyrrolidone) has a molecular weight ranging from about 40,000 to about 1,300,000.
14. The method of claim 12 where the poly(vinyl pyrrolidone) has a molecular weight of about 55,000.

15. A method of preparing hollow nanostructures comprising:
  - obtaining a solution of solid nanostructures comprising at least one metal,
  - selecting a salt of a second metal, wherein the first metal can reduce the salt, and
  - blending a sufficient amount of the salt with the solid nanostructure solution to enable the formation of hollow nanostructures.
16. The method of claim 15, wherein the salt is HAuCl<sub>4</sub>.
17. The method of claim 15 wherein the amount of the salt is sufficient to yield hollow nanostructures comprising substantially non-porous walls.
18. The method of claim 15 wherein the amount of the salt is sufficient to yield hollow nanostructures comprising porous walls.
19. The method of claim 15 wherein the solid nanostructures comprise nanocubes and the hollow nanostructures comprise nanoboxes.
20. The method of claim 15 wherein the solid nanostructures comprise nanospheres and the hollow nanostructures comprise hollow nanospheres.
21. The method of claim 15 wherein the solid nanostructures comprise half cubes and the hollow nanostructures comprise hollow half cubic boxes.

22. The method of claim 15, wherein the solid nanostructures comprise nanowires and the hollow nanostructures comprise nanotubes.
23. The method of claim 15, wherein the sufficient amount of metal salt is determined by preparing a solution of the salt, adding the solution dropwise to the nanostructure solution, and examining the solution on a microscope to determine the progress of the reaction following the addition of each drop.
24. The method of claim 15, wherein the solution of solid nanostructures comprises 5 mL at a concentration of  $4 \times 10^9$  particles/mL and the amount of metal salt added is 1.5 mL at a concentration of  $1 \times 10^{-3}$  mol/dm<sup>3</sup> in aqueous solution.
25. The method of claim 15, wherein the solid nanostructures comprise silver.
26. The method of claim 25, wherein the hollow nanostructures comprise gold/silver alloy.
27. The method of claim 25, wherein the hollow nanostructures comprise a metal alloy comprising at least one of palladium/silver alloy and platinum/silver alloy.
28. The method of claim 15, wherein the solid nanostructures comprise nickel/cobalt alloy.

29. The method of claim 28, wherein the hollow nanostructures comprise at least one of (1) silver/nickel alloy and silver/cobalt alloy and (2) gold/nickel alloy and gold/cobalt alloy.

30. A hollow nanostructure comprising:

a metal alloy, having a hollow shape and substantially non-porous walls, wherein the nanostructure results from a replacement reaction with another metal.

31. The nanostructure of claim 30 wherein the metal alloy comprises gold/silver alloy.

32. The nanostructure of claim 30, wherein the metal alloy comprises at least one of (1) palladium/silver alloy, (2) platinum/silver alloy, (3) silver/nickel alloy and silver/cobalt alloy and (4) gold/nickel alloy and gold/cobalt alloy.

33. A hollow nanostructure comprising:

a metal alloy, having a hollow shape and porous walls, wherein the nanostructure results from a replacement reaction with another metal.

34. The nanostructure of claim 33, wherein the metal alloy comprises gold/silver alloy.

35. The nanostructure of claim 33, wherein the metal alloy comprises at least one of (1) palladium/silver alloy, (2) platinum/silver alloy, (3) silver/nickel alloy and silver/cobalt alloy and (4) gold/nickel alloy and gold/cobalt alloy.

36. A method of preparing a nanostructure comprising a first structure encapsulated by a nanoshell comprising:

obtaining a solution of nanoparticles comprising a first metal;

plating the nanoparticles with a second metal which is different from the first metal; and

reacting the plated nanoparticles with a solution containing a salt of a third metal, wherein the second metal is capable of reducing the salt.

37. The method as recited in claim 36, wherein the first metal is an alloy.

38. The method as recited in claim 36, wherein the second metal is an alloy.

39. The method as recited in claim 36, wherein the first metal and third metal are the same.

40. A nanostructure comprising a first structure encapsulated by a nanoshell comprising:

a nanostructure core formed of a first metal, and

a nanoshell formed of a second metal, wherein the nanoshell encapsulates the nanostructure core, and

wherein the nanostructure core and nanoshell are separated by a space along at least a portion of the circumference of the nanostructure core.

41. The nanostructure as claimed in claim 40, wherein the core is unattached to the first nanoshell so that it can move freely within the nanoshell.

42. The nanostructure as claimed in claim 40, wherein the nanostructure is solid.

43. The nanostructure as claimed in claim 40, wherein the nanostructure is hollow.

44. The nanostructure as claimed in claim 40, wherein the nanostructure comprises at least one additional nanoshell encapsulating the nanostructure.

45. The nanostructure as claimed in claim 40, wherein the first metal is an alloy.

46. The nanostructure as claimed in claim 40, wherein the second metal is an alloy.